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# Teaching Spatial Thinking and Geospatial Technologies Through Citizen Mapping and Problem-Based Inquiry in Grades 7-12

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## ABSTRACT

Our project introduced students in grades 7 through 12 to spatial thinking and geospatial technologies in the context of challenges in their community. We used a mix of levels of inquiry to advance learning from teacher- to student-guided through a citizen mapping group activity. Student-suggested problem-based topics included parks and community gardens, crime, housing, and youth employment opportunities. Qualitative methods were used to evaluate students' knowledge of spatial thinking and geospatial technologies, including map interpretation, a case study, daily exit slips, and interviews. Overall, the students' awareness of their community, spatial thinking, and geospatial technologies increased as a result of participation.

**Key Words:** *problem-based learning, inquiry learning, citizen mapping, grades 7–12*

*M. Beth Schlemper is an associate professor in the Department of Geography and Planning at the University of Toledo, Toledo, Ohio, USA.*

*Brinda Athreya is a Ph.D. candidate in the Department of Geography and Planning at the University of Toledo, Toledo, Ohio, USA.*

*Kevin Czajkowski is a professor in the Department of Geography and Planning at the University of Toledo, Toledo, Ohio, USA.*

*Victoria C. Stewart is an associate professor in the Department of Curriculum and Instruction at the University of Toledo, Toledo, Ohio, USA.*

*Sujata Shetty is a professor in the Department of Geography and Planning at the University of Toledo, Toledo, Ohio, USA.*

## INTRODUCTION

Geospatial technologies, such as cartography, geographic information systems (GIS), remote sensing, photogrammetry, and data acquisition and analysis, are among the tools that support learning about and interacting with the world around us. Often students are unaware of how these technologies impact their lives and have the potential to transform society. “Geospatial technology affects almost every aspect of life, from navigating an unfamiliar neighborhood to locating the world’s most wanted terrorist” (Cimons 2011, 1). According to the U.S. Department of Labor, jobs using geospatial technology are projected to grow 19 percent between 2016 and 2026 (Bureau of Labor Statistics 2017). As such, there is a need to develop education and training materials for middle and high school students in this area and increase awareness of these opportunities.

In 2010, the National Assessment of Educational Progress reported that map reading improves with age and grade level. More important, the use of geospatial technologies can improve spatial thinking in students (Keiper 1999; Shin 2007). Students who learn to use geospatial technologies in grades 7 through 12 will have an advantage in pursuing careers in this rapidly developing field. For employability, geographers are expected to be proficient in the use of geospatial skills and have a comprehensive knowledge of the discipline and other general skills, such as communication, teamwork, and leadership abilities (Solem, Cheung, and Schlemper 2008). The GeoTech Center, the Employment and Training Administration, and a group of industry experts continue to update an interactive geospatial technology competency model that outlines the kinds of competencies (personal, academic, workplace, industry-wide technical, and sector-specific skills) that will prepare students for careers in this area (Geospatial Technology Competency Model 2017). To achieve this kind of expertise, geographical sciences and geospatial technologies should be taught and included in the core curriculum of grades K through 12.

To this end, the Obama administration hosted the first White House Summit on Next Generation High Schools in November 2015 (White House Summit on Next Generation High Schools 2015). These schools are envisioned to encourage students, especially from underrepresented groups, to pursue degrees and careers in science, technology, engineering, and mathematics (STEM) related fields (White House Summit on Next Generation High Schools 2015). The focus was on innovative and *personalized* learning experiences that prepare students for post-secondary education and careers in STEM. Many of the current efforts that were highlighted at the summit included education that allows students to learn skills and knowledge in increasingly complex ways in the context of their communities all over the country. A commitment to teaching and learning methods that engage and empower students was a key component of the agenda.

Aligning with the purposes of the summit, one goal of our project was to improve students' spatial thinking and geospatial technology skills through citizen mapping. This includes the collection of geospatial data by individuals in order to make informational maps for a variety of purposes, particularly for illustrating challenges in their community and proposing improvements to key stakeholders. A related goal of this research was to engage students who have traditionally been underrepresented in the discipline of geography in learning about the neighborhood around their school in new and exciting ways through inquiry and problem-based learning (PBL). By participating in community-based inquiry projects, students were able to relate to the material through personal connections (Mohan 1995 as cited in Barcus and Muehlenhaus 2010). Exploring real-world community issues had the added benefit of motivating students to learn and apply the strategies of using geospatial tools to potential career paths. Our project aimed to start with what students already knew and cared about in their community and build on these interests to introduce them to the kinds of geographic and general skills that could enhance their awareness of potential careers and educational pathways. Further, integrating citizen mapping into the curriculum enabled students who are familiar with their neighborhoods to have a sense of contribution in their communities while learning important concepts, skills, and technologies.

Our primary research questions were as follows: (1) How can citizen mapping be used to promote problem-based inquiry learning and introduce students to geospatial technologies? (2) How does the use of spatial thinking, geospatial technologies, and citizen mapping enhance students' knowledge of their communities? Our hypothesis was that students' knowledge of both skills and their communities would be enhanced through a problem-based, authentic learning experience that focuses on real-world topics that they care about, while using citizen mapping as a tool that fosters an open-inquiry approach to learning.

## INQUIRY LEARNING, PBL, AND CITIZEN MAPPING

Increasingly, educators and researchers are recognizing the value of inquiry learning and PBL in introducing geographic facts, concepts, and skills to students across all grade levels. In a special issue on scientific inquiry in *The Journal of Mathematics and Science: Collaborative Explorations*, the Virginia Mathematics and Science Coalition Task Force argued, "Inquiry is at the heart of the scientific enterprise and, as such, demands a prominent position in science teaching and learning" (Virginia Mathematics and Science Coalition Task Force 2013, 7). Researchers involved in producing *A Road Map for 21st Century Geography Education* suggested that inquiry learning, and more specifically PBL, has the potential to "support or promote the development of geographic knowledge,

skills, and practices" (Bednarz, Heffron, and Huynh 2013, 43). While inquiry learning and PBL are both forms of active learning, not all inquiry learning is problem-based.

Inquiry learning is linked to constructivism and Dewey's work, which advocated for students learning by doing and thinking (Thomas et al. 2013; Key and Owens 2013; Dewey 1930). Inquiry learning may or may not include hands-on activities. However, for an activity to be considered inquiry, it must satisfy two conditions. From the science education perspective, inquiry activities involve "research questions and the opportunity to analyze data" (Virginia Mathematics and Science Coalition Task Force 2013, 8). While data should be analyzed by students in the inquiry process, it does not have to be collected by them. There are also varying approaches to the origins of the research questions from teacher-provided to student-suggested, which are part of a continuum of inquiry learning.

Spronken-Smith et al. (2008) suggested that inquiry learning consists of the following "essential" elements:

- Active approach to learning
- Question-driven or research focused
- Inductive approach to teaching
- Student-/learner-centered with teacher as a facilitator
- Facilitated/scaffolded learning
- Constructivist

They also included a number of optional attributes for inquiry learning, such as collaborative learning, community involvement, interdisciplinary approach, and field-based activity (Spronken-Smith et al. 2008, 72). Geography has traditionally integrated both of these essential and optional attributes into teaching and learning, which provides ample opportunities for inquiry learning in the curriculum.

Common elements of active, inquiry learning that promote the student as learner and the teacher as facilitator are captured in levels of inquiry models (Herron 1971; Rezba, Auldridge, and Rhea 1999; Bell, Smetana, and Binns 2005; Banchi and Bell 2008). The College Board Advanced Placement Program for Science recommended these four levels of inquiry as a means for increasing students' involvement in scientific inquiry in the classroom (AP Science 2018). The model progresses from teacher-led inquiry, with all steps of the learning process provided to the students in confirmation inquiry, toward student-led inquiry, where students perform all of the steps and the teacher facilitates the learning process in open inquiry (Table 1). The level of inquiry utilized is often dependent on the stage at which students have been introduced to concepts, methodologies, or tools as well as the overall learning goals and objectives.

For example, if students have limited experience in using GIS and the goal is to introduce them to the

**Table 1.** Levels of inquiry learning and guidance provided to students.

| Level of Inquiry  | Problem given? | Procedures given? | Answers provided? |
|---|----------------|-------------------|-------------------|
| <b>1-Confirmation</b><br><i>Teacher-led inquiry where all steps are provided to the students.</i><br>Example: Providing a GIS “cookbook” with the topics, procedures, and answers.                                      | ✓              | ✓                 | ✓                 |
| <b>2-Structured</b><br><i>Teacher-facilitated inquiry that leads to students finding the answer.</i><br>Example: GPS treasure hunt with guidance provided for how to use the GPS device.                                | ✓              | ✓                 |                   |
| <b>3-Guided</b><br><i>Teacher provides problem and students determine appropriate methods to find solutions.</i><br>Example: Urban planning activity that requires students to create the best bus routes for the city. | ✓              |                   |                   |
| <b>4-Open</b><br><i>Student-led inquiry where all steps are performed by students and teacher facilitates.</i><br>Example: Students’ citizen mapping projects.  |                |                   |                   |

Adapted from Rezba, Auldridge, and Rhea (1999).

software, a teacher is likely to use confirmation inquiry, providing a topic, data, step-by-step instructions, and the solution in the form of a GIS cookbook. To promote enthusiasm for learning new techniques and introduce students to using a GPS unit, a GPS treasure hunt can be designed around a teacher-provided problem and an explanation of how to use the device while students are required to then find the solution. As students gain confidence in thinking spatially and using various geospatial technologies, teachers can introduce potential problems and students can determine which procedures are appropriate to find answers. For instance, an activity centered on designing the best bus routes that are both economically feasible and meet the needs of riders in the community could provide students with a challenging spatial problem. With increased familiarity with the software and its applications to social problems, teachers may choose to transition toward open inquiry to allow students to frame their own questions and determine whether geospatial technology can help them discover and demonstrate potential solutions through citizen mapping.

According to Golightly and Raath (2015), “Constructivism involves a shift of ownership of learning from the teacher to the student” (58). PBL is one way to promote active learning and to encourage student-led inquiry. For PBL to be effective as a method of higher-level inquiry learning, a shift from teacher as “information provider to facilitator” needs to occur (Yeung 2010, 196). Thomas et al. (2013) explained, “Through PBL, students ask scientific questions relevant to their lives, collect evidence, and develop explanations based on the evidence obtained” (95). Further, Pawson et al. (2006) suggested that “geography has a long tradition of group work, which underlies most practices of PBL” (109). In summary, a few of the key objectives of PBL include fostering critical thinking, empowering students, encouraging cooperative learning, and raising students’ interests in the learning process.

PBL typically starts with the presentation an “ill-structured, complex problem” with “many solutions and many paths to solutions” by the teacher to the students (Halvorson and Wescoat 2002, 92; Golightly and Raath 2015, 59; see also Shepherd and Cosgrif 1998). Following these guidelines, this first stage of PBL seems to reflect teacher-guided inquiry. However, PBL has been described as an iterative process in which students work in teams and are guided by instructors throughout the entire inquiry process. Halvorson and Wescoat explained, “Throughout these stages, the role of the instructor is to facilitate the process of inquiry and to offer constructive comments and guidance” (Halvorson and Wescoat 2002, 92). Although PBL starts with a problem identified by the instructor, students work in groups to create hypotheses based on what they initially know about the issue. In the second stage, students use a variety of primary and secondary data sources to explore their original hypotheses. This prepares them to “evaluate and critique their understanding of the problem” in the third stage (Halvorson and Wescoat 2002, 92). As a result of their research and reevaluation of the problem, students may choose to revise their original hypotheses multiple times. In the final stage, students synthesize and analyze their findings and present a number of possible solutions to their problem (Halvorson and Wescoat 2002; Golightly and Raath 2015).

While these traditional stages of PBL align with inquiry and scientific inquiry, a rigid adherence to these guidelines can be restrictive and prohibitive in middle and high school settings, where time is limited and teachers face pressure to tie instruction to disciplinary standards and to prepare students for standardized tests. As a result, modified versions, or “hybrid models” of PBL, can be used in these settings. In Halvorson and Wescoat’s study of PBL applied to international water problems in undergraduate courses, students revised their hypotheses multiple times (Halvorson and Wescoat 2002). In a modified approach to accommodate time limitations, for example, students may

**Table 2.** Design criteria for summer workshops and curriculum.

| Criteria   | Description   |
|--|---|
| Reveal what students know and understand                     | Assess prior knowledge/understanding and then provide frequent opportunities for student discourse, thinking aloud and writing about what they think they know and how they know it to engage schemata and address possible misconceptions    |
| Reveal what students want to know and why                    | Regular opportunity to engage in disciplinary discourse and reflection by students on the value, purpose, or interest in what they are doing, what questions they have, who might be interested in their work, and why that work is important |
| Support student research and problem solving                 | Student-centered inquiry, where they identify, research, and suggest solutions to problems of interest to them  |
| Require geospatial tools                                     | The use of geospatial data, tools, and technology are integral to the activities  |
| Employ a multidisciplinary approach                          | Students address real-world content with a multidisciplinary perspective  |
| Engage students authentically with careers                   | Through case studies, applications of skills to careers, and interactions with professionals to promote connections among skills, content, and careers  |
| Integrate disciplinary standards for key concepts and skills | Activities are tied to appropriate disciplinary standards that include target content and skills and are introduced in increasingly complex ways  |

have fewer group meetings or revise their hypotheses only once after collecting data, rather than making multiple revisions of their inquiry questions. Based on the dynamics of grades 7–12 education, we integrated a modified, condensed version of the traditional PBL approach into our project design and ultimately into the curriculum modules that emerged from the research. In addition, our modified version of PBL starts with students suggesting an “ill-defined, complex problem” rather than having one proposed to them by the teacher. This is one way to empower the students and raise their interest in learning, which is also indicative of PBL. Similar to the traditional stages of PBL, students collect primary and secondary data in a variety of formats, reconvene to critique their original hypotheses based on new knowledge, synthesize and analyze their data, and propose and present potential solutions.

An important goal of our study was to introduce students to spatial thinking and geospatial technologies in the context of their neighborhood, a familiar environment. Citizen mapping was used as a pathway for illustrating the value of a geographic approach to identifying community challenges (problems) and proposing solutions. In short, citizen mapping is a form of citizen science where individuals collect data and create maps in order to enact political, socioeconomic, or social change. As a teaching and learning tool, the process allows students to participate in open inquiry and PBL, while it also includes a number of geospatial and general skills that prepare students for geography-related careers. Based on best practices in the literature and input from our teacher advisory committee, the design criteria for our summer workshops and related curriculum modules

are linked to the goals of inquiry learning and PBL (Table 2).

In proposing problem-based inquiry questions, students are provided opportunities to discuss and outline what they know about them, what they want to know about their questions, and why their questions are important. This serves the purpose of giving their questions relevance and empowering them in the learning process, which is reflective of PBL. In addition, student-centered inquiry is applied to research and problem solving through the use of geospatial data, tools, and methods. As students explore a variety of data sources, including collecting primary data, examining online databases, and listening to community members who specialize in their topics from different perspectives, they are exposed to the multidisciplinary aspects of their problems as well as to potential career paths. While these components are designed to make learning real and significant to students’ lives, it is equally important to tie this learning to disciplinary content and standards so that teachers can apply these methods in their classrooms.

More specifically, we integrated student-defined questions and students’ proposed solutions, which are indicative of open inquiry, and we provided hands-on instructions for the procedures, particularly in regard to using spatial thinking and geospatial tools. Initially, we purposefully guided students with the procedures, which is common in both confirmation and structured inquiry. In this case, the focus was on teaching the students the methods or procedures in the context of PBL. As a result, it does not appear that our approach fits neatly into the boxes of increasing levels of inquiry learning (see again Table 1). However, a closer look at our methods and



Table 3. Problem-based topics and inquiry activities, Summer 2016.

| Topics           | Problems   | Hypotheses   | Inquiry questions  | Activities  | Findings   | Solutions   |
|------------------|--|--|--|---|--|---|
| Crime            | High crime rates; abandoned properties; overgrown vegetation; poverty; impact on youth | There is more crime on the east side compared to the west side of the school; there are different types of crimes; it occurs at different times of the day; crime can be prevented | In what areas do crimes occur? How do people try to prevent crime? What are indicators of crime in the neighborhood? | Brainstorm how to identify high-crime areas; collect data in the neighborhood by using specific identifiers (memorials, police blue lights; house alarms; security signs); examine crime maps online (ArcGIS, newspaper, police records)  | Crime rates in the neighborhood are 29%–41% higher than the national average; people have a 1 in 25 chance of being a victim of a crime on the east side of school and 1 in 27 on the west side; fewer police blue lights than expected; many homes had alarms or security lights; crime is everywhere but more on the east side | Place more cameras and alarms on houses adjacent to open spaces; create more parks and recreational spaces; more jobs for youth to reduce free time for crime; indoor and outdoor winter activities; extended hours at youth centers                            |
| Youth employment | Unemployment; poverty; crime   | Not enough opportunities for youth; not enough safe places for youth; some turn to gang violence and crime; more employment opportunities would reduce crime                       | Where are the job opportunities in the neighborhood? Where are the recreational opportunities?                       | Brainstorm community assets and needs; create a list of community needs and choose the two most important; compare businesses and institutions on east and west sides of school; assess number of vacant lots; collect and map primary data of employment opportunities and recreational sites; examine secondary employment data | Unemployment and crime rates in the school neighborhood higher than the national average; not many employment opportunities in the immediate neighborhood; a lot of vacant lots; many nonprofit organizations in the neighborhood  | Encourage businesses to hire teens; bring new businesses into empty buildings in the neighborhood; encourage churches, schools, and nonprofits to work together to increase employment and recreational opportunities; create a youth mentorship career program |
| Housing          | Abandoned and neglected properties; foreclosures; rentals; blight; crime               | Abandoned properties impact the value of adjacent homes and contribute to neighborhood blight  | Do abandoned houses impact the value of other houses in the community?   | Fieldwork to identify abandoned properties; collect and analyze property value data online; create tables to compare changes in property values; create maps in ArcGIS online   | Some of the houses they thought were abandoned were occupied; learned that there were more abandoned houses on the east side of the school than on the west; house values had declined more in their neighborhood than the city median values  | Remove abandoned houses; convert abandoned houses into recreational facilities for youth and the community; create opportunities for remaining residents to purchase abandoned properties at a reduced rate   |

(Continued)

Table 3. (Continued).

| Topics                      | Problems   | Hypotheses   | Inquiry questions   | Activities   | Findings  | Solutions   |
|-----------------------------|--|--|---|--|---|---|
| Parks and community gardens | Environmental justice; blight; access to amenities; food deserts | Neighborhood parks need improvement; a variety of park types; parks impact the quality of life in the neighborhood | Are there more recreational activities available to those outside of this neighborhood? | Fieldwork in neighborhood parks and gardens to identify the locations, types, and amenities; analysis of secondary data about parks in the community; create graphs and maps; compare park types in the metro area | Found that the neighborhood had more parks than other districts in the city, but they are small pocket parks and have fewer amenities than other schools' neighborhoods; discovered racial disparities related to access to amenities | Improve existing neighborhood parks by maintaining them and adding amenities; add more parks within walking distance by using abandoned properties; recruit people in the community to adopt a park |

related case studies will illustrate how and why we combined various levels of inquiry, including both teacher- and student-led inquiry. In the process of guiding students in using spatial thinking and geospatial technologies, an important transition from teacher-prescribed to student-designed procedures occurred that allowed students to develop an appreciation and greater understanding of using this approach to address their inquiry questions. Our focus was on illustrating how spatial thinking and geospatial technologies provide a means to engage students with community challenges that they care about through PBL and citizen mapping. The aim was to provide them with the methods and tools to prepare them to be active, engaged citizens.

## METHOD

### *Designing and Implementing the Summer Workshops*

In order to implement the goals established in this project, two summer workshops were held in 2015 and 2016 at a local high school in Toledo, Ohio. The project team consisted of four experienced researchers and teachers representing four different disciplinary backgrounds, two Ph.D. students, and an external evaluator. One of the earliest steps in the project was to create a teacher advisory committee consisting of both social studies and science teachers. Their purpose was to provide guidance to the project team regarding workshop design and format, curriculum, assessment vehicles, and nuts and bolts suggestions.

The first summer workshop in June 2015 served as a pilot for testing project goals as well as the effectiveness of individual activities and the project as a whole. While we started out with ten high school students, eight of them stayed for the entire two-week workshop. All of the students were African American (three females and five males) in grades recently completed as follows: 7th (1), 9th (1), 10th (1), 11th (3), and 12th (2). In June 2016 we were more successful in recruiting participants through lunchtime visits to the school to advertise the workshop and by hiring two high school teachers as consultants who also served as additional instructors during the workshop. They were instrumental in recruiting students and in assisting with student groups in 2016. As a result, the number of students increased to seventeen: Sixteen were African American and one was of more than one race (seven females and ten males), having finished these grades: 8th (1), 9th (5), 10th (4), 11th (3), and 12th (4).

Some of the highlights of the workshops included a GPS treasure hunt, drone demonstration, geocaching, fieldwork in the community, and a variety of geospatial computer games.<sup>1</sup> The initial introduction to geospatial technologies started with simple online games and activities as well as hands-on outdoor GPS activities to assess the students' geographical knowledge and perceptions about space as well as their familiarity with the tools. Building on these experiences, students were introduced

to ArcGIS Online by using a “cookbook” created by the project’s graduate student research assistants. Using the topic of mapping fish movement, the cookbook provided an introduction to the basic terminology of GIS, such as base layers and buffers. For example, step-by-step instructions related to applying a buffer for a mile and downloading information from ESRI databases were included as the students worked with the fish data provided to them. The ArcGIS Online cookbook exercises, which are representative of teacher-led inquiry, prepared the students for more complex levels of inquiry. Later, students entered data they collected in the neighborhood with GPS units and compared it to databases embedded within the program. Our format for learning focused on an introduction of geospatial skills and concepts through fun activities progressing toward a more challenging and data-rich citizen mapping group project, aligning with a shift from teacher-led to student-led inquiry.

As the two-week summer program progressed, the goal was to introduce students to more complex geographic concepts by applying new skills to address concerns they had about their neighborhood. Students used inquiry learning and a problem-based approach to explore topics they recommended, such as crime, youth employment, housing, and parks and community gardens. Table 3 includes the specific real-world community challenges the students suggested and explored along with their potential solutions during summer 2016. A detailed examination of the inquiry activities conducted by the parks and community gardens group is included in the findings section below.

The first step in the PBL inquiry process was brainstorming in small groups of three or four students and two or three workshop organizers to identify neighborhood challenges. Students discussed what they already knew about their selected topics, what they wanted to know, and why it was important. The students created their own inquiry questions, and some groups subsequently revised them after conducting preliminary research in the neighborhood. The teams convened often throughout the learning process to share their ideas and discuss the new knowledge they had acquired collaboratively. They collected both primary data (e.g., GPS data, photos, and observational notes while engaging in fieldwork) and secondary data (e.g., local land bank data, county GIS database, census records, and ArcGIS Online maps). Students created citizen maps of abandoned houses, surveillance markers (cameras, security signs), parks, open spaces, youth employment opportunities, and potholes in their neighborhood. Finally, students communicated their findings to key community stakeholders, using a presentation template developed by the project leaders to facilitate the organization of their research process, their findings, and potential solutions to their problems.

### **Data Collection**

The project team hypothesized that students would have little experience in using geospatial technology or in thinking spatially. One of the challenges in teaching and learning geospatial technologies is that students often have limited background in using tools such as Google Earth or Google Maps. Even the task of finding their own neighborhoods on a map or interpreting 3D visualizations of the neighborhoods can be difficult. To evaluate the students’ prior knowledge of spatial thinking and geospatial tools, we included a number of informal baseline assessments during the first few days of the workshop. Students’ image interpretation and map reading skills were assessed at the beginning of the workshop through a series of map reading and interpretation activities. This step was important for understanding what students knew about geospatial technologies, particularly as applied to their everyday lives. At the beginning of the workshop, not only did students not appreciate the application of geospatial technologies in their lives but they had limited knowledge of them overall.

For example, students were provided with two satellite images of the United States, one with and the other without political borders, to evaluate their spatial skills and geographical knowledge. The students were asked to identify specific states, cities, the Great Lakes, the Grand Canyon, national parks, and other physical features. This pre-assessment activity was administered by the project team. Students completed both sets of questions individually and with the help of the staff, who made informal observations about the students’ ability and knowledge levels.

In addition, students’ map-reading skills were examined through their interpretations of historical maps of the city where the workshops occurred. They were asked to identify specific components of the map, such as the north arrow, scale, title, latitude/longitude, and the legend. To assess their knowledge of map interpretation further, they were also prompted to identify any missing features on the map or to identify areas of the map that were difficult to understand. Students required a lot of individual assistance to complete the questions as they attempted to interpret the map of the city, which indicated that their map interpretation skills were limited or basic.

Based on these informal assessments during the pilot phase of the study in Summer 2015, formal data collection was limited primarily to Summer 2016. In this paper, we address three data collection tools, which are related to our primary research questions. First, we observed the students groups as they worked through their inquiry questions, collected data, and participated in citizen mapping. A case study of the “parks and community gardens” student group provides evidence of an increase in understanding of their neighborhood and an improvement in their spatial thinking skills.



Second, we asked students to complete daily exit slips throughout the course of the workshop as a formative feedback survey. Collected at the end of each day, the survey asked students to respond to three open-ended prompts referring to each day's activities: (1) what they liked most; (2) what they liked least; and (3) what they learned that was most interesting to them. Space was also provided for student comments or questions. This information was used to make adjustments in future activities when possible.

Third, individual interviews provided more nuanced details of students' experiences using technology in the neighborhood during the workshop and what they learned about the community. In Summer 2016 we conducted interviews with fourteen of the seventeen students who participated because one student opted out and two students were absent on interview day. We asked a range of questions about what they learned about geospatial tools and the community to evaluate the goals of our project. Students were interviewed by the workshop leaders who had worked most directly with their groups. The interviews were videotaped and then transcribed verbatim. The transcripts were uploaded into a computer-assisted qualitative data analysis program, MAXQDA, where we used emergent coding based on the responses of the students.

## FINDINGS AND DISCUSSION

### *Case Study*

In Summer 2016, four student groups examined a variety of social, environmental, and economic issues. In this section, we highlight one of the groups to illustrate how PBL and inquiry learning allowed students to think spatially and practice using geospatial technology to address their inquiry questions. This case study shows how the design criteria in [Table 2](#) were integrated into the workshop design and the project goals of promoting a more open-inquiry learning environment. Citizen mapping was used as a tool to promote spatial thinking and the use of geospatial technologies and supported collaborative learning and problem solving.

The focus case study is the parks and community gardens group, which consisted of four students (three African American females—two who had just finished 11th grade and one 12th grade—and one African American male, who had just completed 12th grade). This group of older students was facilitated by two instructors, a white male university faculty member and an African American female high school math teacher. More specifically, the project instructors participated in discussions, provided instructions for using technology and ArcGIS Online, and guided the students in the research process. All of the student groups practiced their final presentations twice, including opportunities for peer review and revisions as well as a dress rehearsal before formally describing their projects and

recommendations to key community leaders, their families, and school district personnel.

Among their first set of tasks was to choose a topic of interest and brainstorm what they knew and wanted to know about it. The students reported the following as what they already knew about community parks and gardens in the neighborhood around the school:

- We have a community garden by our school.
- There are other gardens around the neighborhood.
- Parks have playgrounds.

In regard to what they wanted to find out, they asked the following initial questions:

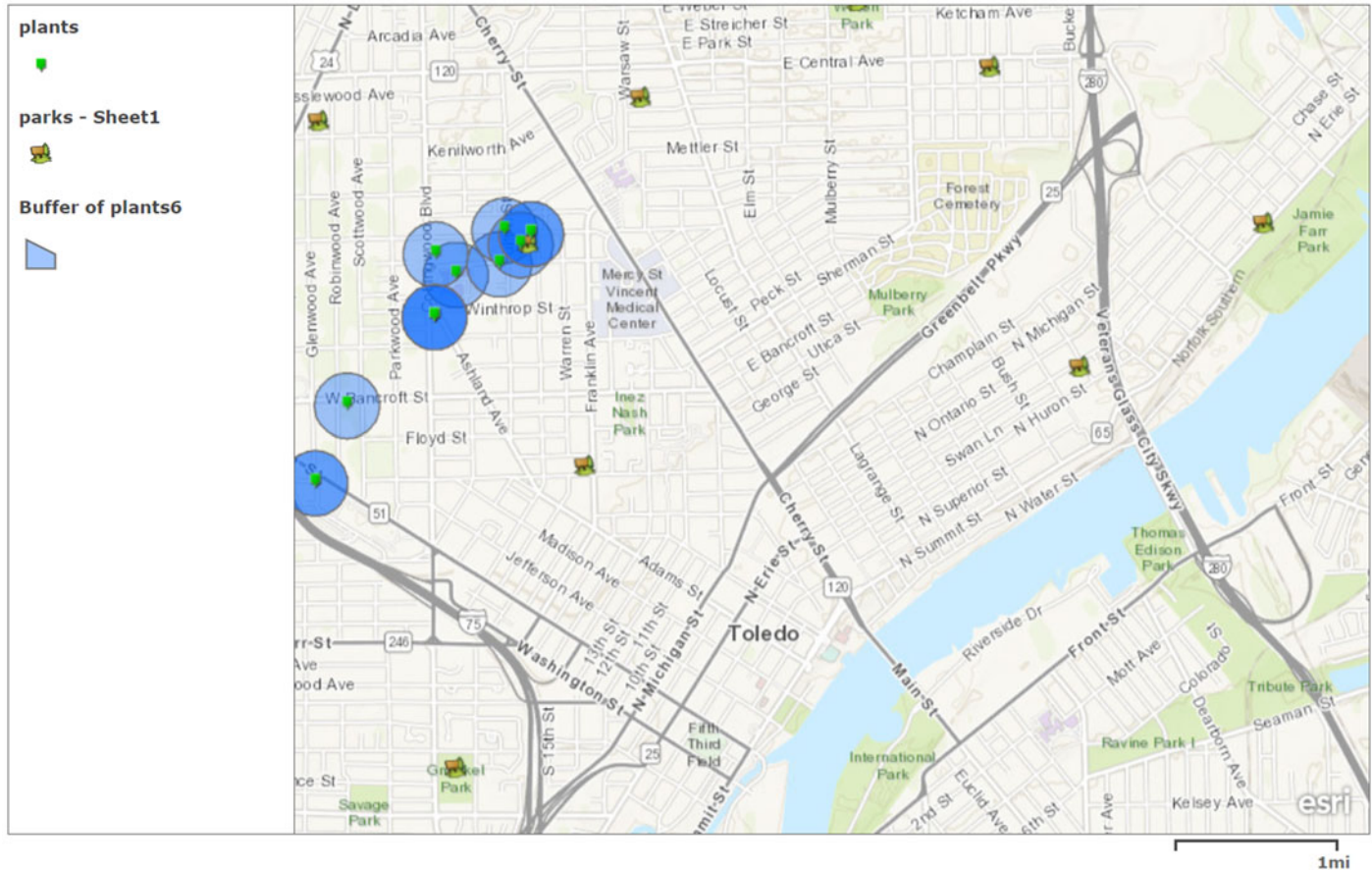
- How much does it cost to renovate a park?
- How can we get more people to work on gardens?
- What can we plant that will help our community?
- What is considered a park?

This group explained that this topic was worth researching because improvements in parks and gardens are an investment in the community.

While this group started with a number of potential inquiry questions, including how parks and community gardens are defined, their primary inquiry question was, "Are there more recreational activities available to those outside our high school community?" Their shift from basic questions about community parks and gardens toward comparing the availability and types of amenities in the parks near their high school to other neighborhoods was inspired, in part, by one of the guest speakers during the workshop as well as the research they conducted and the data they analyzed. We invited a number of guests from the local area who work on community issues such as government officials, university faculty members, police officers, planners, neighborhood organizers, land bank and fair housing officials, and public transit authority employees. For this student group, a presentation on the location of city parks by neighborhood that was given by a city councilwoman was both revealing and serendipitous. She provided a handout that listed all of the city parks by district and the type of amenities available in each of the parks. As a result, the students discovered that while the district where their high school is located has the largest number of parks, the majority of them were considered to be "pocket parks," offering primarily contemplative versus active sports recreational opportunities, such as basketball and tennis courts. For them, the *problem* was a matter of environmental justice related to the need for a fairer distribution of services provided to all districts in the city.

The process of finalizing their inquiry question also included two days of fieldwork to collect data about community parks and gardens in the neighborhood around their high school. Using a GPS device, the

## Plants and Parks 2016



**Figure 1.** Parks and community gardens group reference map.

students pinpointed the locations of both parks and community gardens to create a reference map using ArcGIS Online (Figure 1). The mapped features included plants, community gardens, and parks within a one-mile radius of the school. The students used plants primarily in reference to the community gardens they observed. A plant buffer was drawn to show the proximity of each community garden in the area. They observed that plants and gardens are clustered around the school, whereas parks are scattered and spread out from each other. They selected a buffer range of 0.1 miles to show the close proximity of community gardens to the school, which illustrated that they are located mostly near the school, which is two blocks north of Winthrop Street within the clusters of plant buffers and not in other parts of the neighborhood. In addition, they took photos with a GPS-enabled camera to integrate into their research and the presentation of their results and recommendations. The group discussed their observations in the field and in the classroom on several occasions. They observed that although there were 34 parks officially listed by the city in the district surrounding their high school, only three

of those seemed to be in active use based on their fieldwork. They also discovered that many of the existing parks nearby were small, unkempt, and overgrown with vegetation, which deterred students from using them. While their initial plan for fieldwork was to visit the parks and community gardens near the school, they also observed a number of large open spaces in the neighborhood that appeared to be vacant because of the overgrown grass. The students fantasized about using those fields for baseball, tennis, or soccer because the only sports available in the area near the school is a small basketball court.

In addition to fieldwork and collecting primary data, the students used secondary data, primarily the park data provided by the city councilwoman, to determine that the parks in their district did not offer the types of amenities afforded to residents in other neighborhoods. Due to time limitations, the students were not able to conduct research on the history of parks in the community. In addition, they were not able to visit the parks outside of the area where they conducted fieldwork near the school for direct observations. Their personal

knowledge of parks in the city was limited to those near the school as well as one large park with a variety of sports activities located 2.6 miles from their high school, and according to Google Maps a 51-minute walk, which includes navigating high-traffic streets and crossing over a highway. However, they created graphs with the secondary data to illustrate the disparities of types of parks among neighborhoods in the city. They discovered that students in their neighborhood do not have parks within walking distance that provide comparable amenities to other schools. Further, for those parks that are within walking range, busy traffic and congestion impact their safety. They proposed that the city needed to provide their neighborhood with more recreational opportunities within existing parks, and they suggested that citizens could participate in an "Adopt-a-Park" program to provide maintenance for parks in decline. They presented their research and potential solutions to the mayor, the Department of Neighborhoods, and other community leaders.

At the beginning of the inquiry process, the students were not sure how to define a park and were not aware of the disparities among parks within the metropolitan area. For them the problem was one of environmental justice and unequal access to recreational opportunities in city parks. This group used a variety of primary and secondary sources to explore this issue and evaluated their understanding of parks in the process. While there were other possible solutions, such as having the city provide better transportation for students at their school to parks in the suburbs, these students preferred to see enhancements in the parks in their own neighborhood. While the PBL process was condensed, students addressed a problem that they cared about in the community, learned inquiry skills, worked collaboratively, and presented their findings and potential solutions in a public setting.

### *Daily Exit Slips*

To address our questions regarding the impact of citizen mapping as a method to promote problem-based inquiry learning and to enhance students' knowledge of spatial thinking, geospatial technologies, and their community, we asked students a series of related questions each day of the workshop. We wanted to obtain immediate daily feedback from them about what they liked best, what they liked least, and what they learned that was most interesting to them. A summary of the two weeks of responses provides insight into their perspectives of this approach to learning content and skills and reveals links to our curriculum design criteria. Their formative feedback also allowed us to make adjustments in daily activities to transition from teacher-guided instruction to student-led, problem-based inquiry citizen mapping projects.

The results of what students liked most each day, reported in Table 4, suggest that students preferred when they were being productive, autonomous, and engaging in work that they valued, such as doing fieldwork, conducting secondary research, or listening to speakers. Some examples of comments they made on the daily exit slips are provided as exemplars in Table 4. Among the things they liked, students also included learning collaboratively through geospatial technologies, games, and interaction in the neighborhood. These results align with students' statements of what they liked least. Student responses indicate that they did not like sitting through long and/or irrelevant presentations by outside speakers, having to present in front of their peers, or engaging in some of the planned activities, in particular taking the pre- and post-assessments. It should be noted that the most common response to the question "what did you like least today?" was the word "nothing" or no answer. We interpreted this to mean that students liked the planned activities overall, which was reinforced by the comment, "I like everything."

Similarly, when responding with what they learned that was most interesting, students noted that they were interested in activities in which they were able to work collaboratively, engage in research in the field and the classroom, learn something new from speakers, or participate in interactive games. Their responses were evenly distributed among learning geospatial skills, studying their specific PBL topics, and finding out new things about the city and their neighborhood.

Overall, students' comments on the daily exit slips aligned with our project goals, the curriculum design criteria, and the typical characteristics of inquiry learning. Proposing and revising inquiry questions, conducting fieldwork, analyzing data, problem solving, working collaboratively, and presenting results are reflective of the problem-based inquiry learning process. In addition, their daily feedback supported our goal of introducing them to the value of spatial thinking and geospatial technology in understanding their community better and illustrating potential solutions to neighborhood challenges.

### *Interviews*

In addition to gathering daily feedback, we interviewed students at the end of the workshop in 2016. First, we asked students what one or two things from the workshop that they would always remember (with a prompt of perhaps it was when they learned something particularly interesting or one of the activities was really fun). Of the fourteen students who participated in the interviews, 44 percent of the responses ( $n=32$ ) were related to *geospatial skills* (e.g., GIS, GPS, maps, and fieldwork), while 22 percent of the responses were *general skills* (e.g., data collection, analysis, and presentations). Sixteen percent of things remembered were the PBL topics they explored, such as housing, crime, and

Table 4. Highlights of daily feedback from students.

| Codes                         | What did you like most today? |   | What did you like least today? |   | What did you learn that was most interesting to you? |  |
|-------------------------------|-------------------------------|---|--------------------------------|---|--|--|
|                               | <i>n</i>                      | Exemplars   | <i>n</i>                       | Exemplars   | <i>n</i>   | Exemplars  |
| Geospatial skills             | 15                            | GPS treasure hunt; using GPS to collect data; how to use GIS to make a map; fish data activity; maps are important                    | 0                              |   | 20   | Using a GPS; how to use the geo-tracker; GIS is a growing industry that needs more people; ArcGIS thing is pretty interesting; adding layers onto maps; Things we talked about in groups                           |
| Collaboration                 | 19                            | Working or talking with the group; brainstorming together   | 0                              |   | 6  |  |
| Fieldwork and engagement      | 22                            | Finding parks and gardens, houses; looking at buildings; walking around the neighborhood; going outside                               | 3                              | My group couldn't cross Bancroft Bridge [closed for repair] to get back to school; walking around the Old West End neighborhood | 3  | I learned how we can help the community; I learned that the community is very important  |
| PBL research and observations | 2                             | Working on computers; secondary data  | 2                              | Trying to find websites that were blocked [by the school]   | 42   | Where parks were around the school; buying and selling of houses; crime is high in the city; the neighborhood is divided financially; a lot of lead paint in the community How we could make our PowerPoint better |
| Presentations                 | 15                            | Our progress on our slides; getting ready for our presentation; going to the theater  | 11                             | I didn't like speaking in front of people; watching other group presentations; my team needs more speech work                   | 5  |  |
| Planned activities            | 32                            | Enjoyed the guest speaker; the city councilwoman's presentation was interesting and helped our presentation; Geoparty game; Geoguessr | 22                             | Test was boring [pre- and post-tests for data collection]; our team lost the game; plotting the points; the interview we had    | 6  | Geoparty was fun; playing the other games  |
| Miscellaneous                 | 27                            | Pizza; retro photos of the school; being videotaped   | 15                             | Didn't like lunch; it was too hot outside; I liked everything   | 0  |  |
| No response or N/A            | 0                             |   | 62                             | Nothing   | 0  |  |

Note. This table provides a summary of students' daily written feedback with a sample of exemplars. Daily exit slips were collected nine of the ten days of the workshop in Summer 2016.

PBL = problem-based learning; GIS = geographic information systems.



community gardens. According to one of the parks and community gardens group students, "Two things from the workshop that I will always remember is working in groups, gathering information about parks and gardens, and walking around the community to see where these parks and gardens are located." Notably, working in groups and making new friends accounted for 19 percent of their responses.

A second, related interview question asked students what new skills they learned during the workshop. Like the previous question, geospatial skills ranked highly at 65 percent of all responses ( $n=20$ ), while general skills represented 20 percent and working in groups accounted for 10 percent of the factors reported. One student said, "I will always remember ArcGIS because it was a new way of mapping instead of just looking up stuffs on Google Maps. I can actually put different buffers or layers on to actually see and compare things in the community." Another student noted, "I learned how to be a leader, help making maps and working in groups" (sic). Their responses to what they learned that they would always remember and what new skills they learned provide evidence that a problem-based inquiry approach, in this case using citizen mapping, is an effective way to learn content and skills (geospatial and general) through the lens of the students' community.

To determine whether students' knowledge of their community was enhanced by participating in this project, we asked them to explain what they learned. In response to this question, the students overwhelmingly mentioned the topics they explored through inquiry learning, such as parks and community gardens, crime, housing, blight, and youth employment opportunities (twenty-five out of twenty-eight responses, or 89%). Two important discoveries were repeated in their responses, which illustrate the power of spatial analysis and inquiry learning. First, many of the students highlighted differences between the neighborhoods on the east and west sides of their school. A male 9th-grade student said, "I learned that there is a lot more blight, abandoned houses, and crime on the east side and less on the west." These observations were made through both the fieldwork and the citizen maps they created using ArcGIS Online. Second, as each student group presented their research process and results to the other groups, they remarked in discussions during the workshop and in the interviews about the way that their topics overlapped. For example, they were interested in the intersections among lack of employment opportunities for youth, open space that could be used for additional parks, the presence of crime, and neighborhood blight. A female 11th-grade student expressed this well when she remarked, "All of our topics like the parks and gardens, housing, crime, and community assets and needs, it all runs together like in our presentations we will have a piece of each of these topics in our presentations (sic)."

## CONCLUSION AND IMPLICATIONS

While many of the students reported that they chose to participate in the workshop because they wanted to make a difference in the community, they were also very enthusiastic about learning new tools and related technology. They were quick in grasping and exploring the new software that was introduced to them and illustrated that they were capable of handling the software, as demonstrated by the maps they produced. Perhaps most importantly, students felt empowered through the problem-based inquiry process of proposing research topics, researching, analyzing, and presenting their findings and potential solutions to their families and key community stakeholders, including local government officials, school administrators, teachers, and other neighborhood leaders. In regard to improving students' spatial thinking and geospatial technology skills, students clearly felt more confident in their knowledge and ability to use geospatial technologies after applying them in the context of their neighborhood. As for an expansion of knowledge of their communities through spatial thinking, geospatial technologies, and citizen mapping, evidence from students' presentations, daily exit slips, and interviews supported this finding, too. Ultimately, students in our study learned the value of spatial thinking, geospatial tools, and working cooperatively to address challenges in their neighborhood.

Based on these experiences with the two workshops, curriculum modules have been developed that integrate problem-based inquiry learning and innovative uses of technology into topics that address 21st-century issues, while also embedding a focus on careers and learning both general and geospatial skills.<sup>2</sup> We appreciate the hesitation that teachers may have in using PBL and inquiry learning, which can be time consuming, but we found there are many benefits to this approach. We agree with Thomas et al. (2013):

Students of PBL reported feeling empowered and more interested in the learning environment. Furthermore, social impact was often cited as a positive aspect of PBL implementation. Data revealed that students were more willing to share knowledge and participated more actively in cooperative learning than peers in a traditional setting (98).

Student feedback indicated that they enjoyed working in groups to explore neighborhood challenges and appreciated the opportunity to interact with the community as well as present their potential solutions to key community stakeholders.

Further, inquiry learning is embedded in the disciplinary standards of the social studies and the sciences. For example, the "Inquiry Arc" within the College, Career & Civic Life C3 Framework for Social Studies State



Standards is integrated throughout the guidelines for learning content and skills within individual disciplines, while supporting an interdisciplinary approach to social challenges (C3 2017):

Indeed, the study of social sciences enhances student preparation for college, careers, and civic life by promoting critical thinking, inquiry, problem-solving, evidence-based reasoning and communication skills, as well as multi-cultural and global understandings, the ability to work with diverse groups, and a deep sense of personal social responsibility (14–15).

While our workshops included the majority of these essential components, time limitations prohibited us from expanding what the students learned locally to global challenges. As a result, we have created extensions in the curriculum modules that are available on our project website.

Similarly, inquiry learning was integrated across science disciplines in the Next Generation Science Standards framework (NGSS 2013). “Standards that balance and integrate inquiry and content can enhance student learning and better prepare them for success in postsecondary institutions and careers” (NGSS 2013, Appendix C, 12). In addition, some researchers have suggested that inquiry learning has the potential for broadening participation of traditionally underrepresented students in STEM (Lee et al. 2006; Wilson et al. 2010). Science educators, like the social studies, recognize the value of inquiry learning in teaching content, skills, problem solving, improving society, and preparing students for the future.

In conclusion, citizen mapping of local challenges that students are vested in has the potential to increase their awareness of how spatial thinking, geospatial technologies, and problem-based inquiry can benefit society and provide them with paths to further education and careers. Additional research is needed to provide scaffolding of these methods to disciplinary content standards in the social studies and sciences at the state and national levels across the grade levels. This evidence would provide teachers with an even greater incentive to employ inquiry learning in the classroom. Our next steps will include providing professional development opportunities to social studies and science teachers that guide them in integrating problem-based citizen mapping in their classes.

## NOTES

1. Contact the corresponding author for a detailed outline of the workshop format, activities, the

ArcGIS cookbook, and copies of curriculum modules related to the project.

2. Our project website currently includes six curriculum modules with both teacher and student materials in printer-friendly format: <http://www.utoledo.edu/research/advancing-geospatial-thinking/>



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## ORCID

M. Beth Schlemper  <http://orcid.org/0000-0002-4678-0458>  
 Victoria C. Stewart  <http://orcid.org/0000-0003-1454-7296>

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